for not only does the latter present a larger adhesive surface, but the longer claws are more likely to reach beyond the pubescence and the bristles, and fasten to the cellular tissue of the leaf beyond.

In answer to the second question, I can only say that there is nothing exceptional in the power of the larva to withstand the solvent quality of the fluid ; it is, on the contrary, in accordance with the facts known of many species of Muscidæ and Estridæ, some of which, like the well-known horse-bot, revel in a bath of chyme, while others are at ease in the intestinal heat of other warm-blooded animals. It is also well known that they will often live for hours in strong liquids, such as alcohol and turpentine.

Conclusion.—To one accustomed to seek the why and wherefore of things, the inquiry very naturally arises as to whether Xanthoptera and Sarcophaga play any necessary or important rôle in the economy of Sarracenia. Speaking of the Sarcophaga larvæ, Mr. Ravenel asks, "May he not do some service to Sarracenia as Pronuba does to Yucca?" And if so, may not all this structure for the destruction of insects be primarily for his benefit? Can he be merely an intruder, sharing the store of provision which the plant, by ingenious contrivance, has secured for itself, or is he a welcome inmate and profitable tenant? Self-fertilisation does not take place in Sarracenia, and the possibility that the bristly Flesh-fly aids in the important act of pollination lends interest to the facts. No one has witnessed with greater pleasure than myself the impulse which Darwin has of late years given to such inquiries ; but we should be cautious lest the speculative spirit impair our judgments or our ability to read the simple lesson of the facts. My own conclusions summed up are :—

1. There is no reason to doubt, but every reason to believe, since the observations of Dr. Mellichamp, that Sarracenia is a truly insectivorous plant, and that by its secretions and structure it is eminently fitted to capture its prey.

2. That those insects most easily digested (if I may use the term) and most useful to the plant are principally ants and small flies, which are lured to their graves by the honeyed path, and that most of the larger insects, which are not attracted by sweets, get in by accident and fall victims to the peculiar mechanical structure of the pitcher.

3. That the only benefit to the plant is from the liquid manure resulting from the putrescent captured insects.

[Mr. Ravenel, in making a transverse section near the base of the young leaf, noticed large tubular cells passing down through the petiole into the root, and much of the liquid manure may possibly pass through these into the root stalk.]

4. That Sarcophaga is a mere intruder, the larva sponging on and sharing the food obtained by the plant, and the fly attracted thither by the strong odour, as it is to all putrescent animal matter or to other plants, like *Stapelia variegata*, which give forth a similar odour. There is nothing to prove that it has anything to do with pollination, and the only insect that Dr. Mellichamp has observed about the flowers with any frequency, is a Cetoniid beetle, the *Euryomia melancholica*.

5. That Xanthoptera has no other connection with the plant than that of a destroyer, though its greatest injury is done after the leaf has performed its most important functions. Almost every plant has its peculiar insect enemy, and Sarracenia, with all its dangers to insect-life generally, is no exception to the rule.

6. That neither the moth nor the fly have any structure peculiar to them, that enables them to brave the dangers of the plant, beyond what many other allied species possess.

ON EVOLUTION AND ZOOLOGICAL FORMULATION*

IN the means which he has at his disposal for expressing the relative values of the facts of his science the chemist has an advantage over the zoologist which cannot be over-estimated. By a chemical rational formula it is possible to express, in a very small compass, facts of composition and decomposition, as well as many of the other relations borne by the constituents of a compound body one to the other.

In zoology formulation has received but little application ; it has been employed to represent dental series and one or two other numerical points only ; the cumbrous method of detailed verbal description being still resorted to in all cases, even when continuous observation has so accumulated facts, that it is almost impossible to retain the grasp of them without some auxiliary appliances. A method of zoological formulation, which, whilst expressing the facts of anatomical structure, attracts the attention to the relative importance of the observed differences, rather than to the details of the differences themselves, is a great desideratum ; and it will be my endeavour on the present occasion to show how such a method can be made to assist in solving a problem so involved as the true affinities of a group of animals whose variable characters are fairly understood.

But the chemist has the atomic theory as a basis whereon to build ; is there any principle in biology so inclusive as to yield a foundation on which to construct the desired system? Until the introduction of the theory of evolution and the doctrine of natural selection there was not. As long as the negative hypothesis of "special creation" held sway, the interest attached to the study of the mutual relations of organised beings was *nil.* No such relation could, in fact, have existed. But now, through the insight into nature arrived at by the all-embracing theories of Lamarck and Darwin—the Daltons of biology—the pedigree of the animal and vegetable kingdoms will form a problem which it will require many generations of the ablest zoologists to solve, even approximately, by the careful correlation of the undigested, unrecorded, and unobserved facts at their disposal.

Let us stop for a moment to glance at this doctrine of descent, in which, through the struggle for existence, by a process of natural selection, the fittest (for want of a better term) are said to survive. We may compare the living body of one of the higher animals to a cannon counterpoised on a Palliser gun-carriage, so fixed that it will hit a target situated at 1,000 yards distance. Before firing let marks be so made that the different parts of the whole engine can be afterwards adjusted to their former position. The gun is fired ; the target is struck ; a well-defined perforation or indentation is the result. A second similar shot is arranged for, by re-adjusting the engine with the assistance of the marks previously made ; but on this occasion no direct aim is taken. The gun is again fired ; but this time the target is missed, or it is hit in a different part. Why is this? It is because, in the former of the two firings, by the strain it caused to the whole machine, by the wear it produced in the rifling of the gun, and by the slight differences in the quality and quantity of the powder, the shot left the muzzle under different circumstances on the two occasions. The amount of this difference was sufficient, at the long range selected for illustration, to make the alteration in the course taken by the projectile perceptible. An external influence, the wind, is almost certain to have affected the result. This example shows how that minute differences, firstly in internal, and secondly in external circumstances, are sure to prevent the exact accordance of consecutive phenomena which might reasonably have been expected to be fac-similes one of the other.

As a general inference from every-day observation we are similarly led to expect that the offspring of living organisms will resemble their parent forms. But, as with the cannon, there are minor forces which in living beings come into play to produce slight changes in the progeny on all occasions. These changes are likewise of two kinds, depending on the circumstances connected with the parents themselves, and on those acting directly on the offspring from the time of its conception onwards. Amongst the former of these may be included differences in the actual and relative ages of the parents, both of which factors vary with each one of their progeny ; their states of health, and their occupations. Amongst the latter are the habits and climate to which the offspring is subject. Causes of this nature, many of which are very incompletely understood, produce variations in the individuals of a species; and as the offspring resembles its parents, unless extra forces come into play to produce differences, the peculiarities of each variety are capable of transmission to the progeny. Thus, in course of time, strongly marked varieties of a species are likely to be developed; these give rise to others, until the descendants are very different from their ancestral forms. Time, however, besides continuing on the primitive stock and developing new varieties, produces other effects with equal certainty. Animals are dependent for their existence on a certain supply of organised food. Those living forms which furnish it have also been affected in a manner similar to their destroyers; like them, they have varied, and they have tended to become more numerous (the progeny in all cases being more numerous than the parents). The area of occupation being necessarily limited, and, as we are justified in assuming, fully stocked to commence with, the multiplication of the progeny develops a universal struggle for existence, one in which each individual, for self-preservation sake, participates; and in which the weakest goes to the wall. As in other contests, however, so in this, the race is not always to the swift, nor the battle to the strong, for many of the destroying causes are not those which are overt in their attacks. The sickly blade of grass, under the shelter of an overshadowing stone, protected from the browsing herd, fructifies and reproduces itself, whilst its free-growing neighbours form a delicious mouthful for the nibbling sheep. What amount of strength or courage can protect the leader of a flock from the ravages of an intestinal parasite? or prevent the largest individual of a flight of birds from being the most likely, on account of its greater superficial area, to be killed by a random gun-shot? Specialisation of function to resist special attack or to acquire special advantage, is, therefore, on account of the struggle for existence in conjunction with the tendency to vary, a factor of vitality. Specialisation in many directions is elaboration and progress so called; and as man possesses this in the most marked degree, he is considered to be the furthest removed from the living monad which gave him origin.

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* The substance of a lecture, introductory to the evening class of Zoology, at King's College, Strand. By Prof. A. H. Garrod, Fellow of St. John's College, Cambridge.

The pedigree of vitality is evidently, therefore, the greatest problem of biology; for a full comprehension of it includes all the minor details of the science. How is this to be arrived at? From any collection of people which comprises nearly all the living representatives of a family, it is not difficult to obtain a large amount of information with regard to the ancestry of that family by oral interrogation. This will be facilitated by classing together in groups those of equal kinship, placing in the same sections brothers and sisters, in larger divisions those who are first cousins, and so on. It will not be hard to find who were the grandparents of each, some probably being present; the great-grandparents of most will have only been personally known to the older; and more distant relations of the same line, by hearsay alone. Pursuing the investigation, the linking of each retrograde step will be found more difficult, and the difficulty of identifying the ancestor common to them all will be almost insurpassable. When an old family has very few living representatives or none at all, the facilities for studying it will be proportionately diminished.

In zoology the method of investigation for the purpose of classification is very similar. Instead of direct interrogation, answers are arrived at by an appeal to facts of existing structure. Similarity in habits, distribution, and external characters separate off closely related forms from their more distant allies. To solve the more difficult problems of less intimate relationships, recourse must be had to internal characters in addition; to points of difference in osteological and soft-part anatomy, many of which can only be arrived at by prolonged dissection and the employment of every available opportunity.

The difficulty of appreciating the relative value of differences in any group of animals that is forming the subject of investigation, that of separating the realisation of the characters themselves, independently from the words necessary to express them, has led me in the course of my dissections to adopt a method of formulating my results in a manner which at once places them in a form available for ready comparison, and in an order of relative significance; in fact as rational formulæ, which differ in arrangement according to the phases of my general ideas. An example of the application and the applicability of this method may not be without interest, and this I will draw from the sub-order Psittaci, the Parrots.

The parrots form a well-marked, easily distinguishable group, with no outlying doubtful genera; and as with many other well-marked groups, such as the Rodents amongst mammals, and the Umbelliferæ amongst phanerogamic plants, the minor divisions are not so easily determinable. In fact, there is a very great uniformity in all the external and internal characters throughout the sub-order. There are, however, a few points in which they present variations, those best known being (1) in the vessels of the neck, (2) in the ambiens muscle, (3) in the furcula, and (4) in the oil-gland. I will notice each of these points shortly.

Firstly, with regard to the vessels of the neck. In most of the higher animals an artery, the carotid, runs up each side of the neck to supply blood from the heart to the head. In birds these vessels generally run in the middle line of the front of the neck, side by side and in contact. In some parrots, and in them only, whilst the right carotid pursues its usual course, the left, leaving its fellows, runs separately at the side along with the left pneumogastric nerve. In several groups of birds the right carotid is absent, the left alone remaining in its normal position. This is the case with one genus of parrots. Secondly, the little long and slender muscle, the ambiens, whose tendon in its unique course obliquely traverses the front of the knee capsule, is absent in some parrots, being present in others. Thirdly, the furcula or merrythought, which unites the two shoulders by an osseous bow, may be present or absent. Fourthly, the oil-gland, situated just over the tail, is wanting in some genera.

Omitting for the time being the case, which amongst the parrots is found only in the genus Cacatua proper, in which the left carotid alone is present, there are sixteen possible combinations of the four characters under consideration, of which six are found to exist. They are the following:—

1. The carotids are normal; the ambiens is absent; the furcula is present, as is also the oil-gland.—(PALÆORNITHINÆ.)
2. The carotids are normal; the ambiens is absent, as is the furcula, and the oil-gland is present.—(STRINGOPINÆ.)
3. The carotids run abnormally; the ambiens is present, as is the furcula and the oil-gland.—(ARINÆ.)
4. The carotids run abnormally; the ambiens is absent; the furcula and the oil-gland are present.—(PYHRRURINÆ.)
5. The carotids run abnormally; the ambiens is absent, as is the furcula; the oil-gland is present.—(PLATYCERCINÆ.)
6. The carotids run abnormally; the ambiens is absent; the furcula is present; the oil-gland is absent.—(CHRYSOTINÆ.)

The facility for comparison afforded by a formulation of these results will be evident from an inspection of the following Table, in which the presence or absence of structures is represented by the signs + or —; in which the normal condition of the carotid arteries is indicated by a Roman 2, whilst its abnormal state is indicated by the same figure in italics. The relative positions of the four different anatomical facts is retained throughout :—

TABLE I.

	Carotids.	Ambiens.	Furcula.	Oil-gland.
(1) PALÆORNITHINÆ .	2	–	+	+
(2) STRINGOPINÆ . .	2	–	–	+
(3) ARINÆ	*2*	+	+	+
(4) PYRRHURINÆ . .	*2*	–	+	+
(5) PLATYCERINÆ . .	*2*	–	–	+
(6) CHRYSOTINÆ . .	*2*	–	+	–

On this arrangement, the Lories, belonging to the *Palæornithinæ*, their zoological formula is 2 – + + ; whilst that of *Cyanorhamphus*, which is one of the *Platycercinæ*, is *2* – – +. By this means the relations of the different groups to one another are readily recognisable.

Next, in the attempt to arrive at a correct detailed classification, the question as to the zoological formula of the ancestral Psittacine form must be one of primary importance. This can only be arrived at by a comparison of the other bird-types with that of the parrots. Taking the characters employed in Table I., and similarly formulating such birds as the fowl, duck, rail, stork, and cuckoo, they all agree in being represented by 2 + + + (1) ; others, like the kingfishers and hornbills, have the formula 2 – + + (2) ; whilst a third type, with only a left carotid, are included in the L – + + type (3). No others of importance exist. From which of them did that of the Psittaci spring? It must have been from one ; and, peculiarly enough, there are genera to be found among them which closely approach all three, for—

The formula of *Pittacus* is *2* + + +
" " *Palæornis* " 2 – + +
" " *Cacatua* " L – + +

However, this only shows that the sub-order is a very ancient one, and has undergone changes analogous to the whole class *Aves*, and it does not complicate the problem in the least.

There are parrots with two normal carotids, *e.g.* the *Palæornithinæ* ; there are others in which the ambiens is present, *e.g.* the *Arinæ ;* most have a furcula and also an oil-gland.

Now suppose that when steam-engines were first introduced they had all been constructed with steam-whistles attached. Suppose that shortly afterwards several had been exported to different colonies, and that ever afterwards each colony had, with the originals as patterns, gone on constructing them for their own use, improving upon the original design as they thought best. Suppose that by certain individual manufacturers a gong was substituted for the whistle ; in others a bell, and in a third no sounding apparatus at all. A traveller going through the different countries at the present time would probably find whistle-engines wherever he went, though in different places gongs or bells will have replaced the whistle. Knowing nothing about the history of the steam-engine, is he not justified in inferring that it was originally constructed with a whistle ; for otherwise would it be likely that each colony should have independently employed the same method of signalling, when there were several to be chosen from ?

The naturalist, similarly, as an uninitiated looker-on at the contrivances of nature, finds the same type of structure running through forms not very intimately allied ; as, for example, two symmetrical carotids, in reptiles, mammals, and some birds ; or an ambiens muscle in the fowl, the eagle, the cuckoo, and the plantain-cutter. When, therefore, these fundamental arrangements are found to exist (though perhaps not combined in any one individual) in any well-defined group like the parrots, may it not be legitimately inferred that the ancestor of that group possessed them in their full and unmodified form ? Undoubtedly it may ; and on this principle we can almost certainly assume that the ancestral parrot possessed two normal carotids, an ambiens muscle, a complete furcula, and an oil-gland ; in fact, that its formula was 2 + + + ; and that all those species in which one or other of the included characters differ from this *type formula*, they do so on account of forces having modified the ancestral form. This line of argument therefore leads us to infer the extinction of the earliest form of parrot, unless some yet undissected genus is subsequently found to correspond with it ; and all the existing genera must be referred to collateral branches, in which at least one operation of modification has been accomplished. Those which have undergone no further change from the 2 + + + type are the *Palæornithinæ* (2 – + +), and the *Arinæ* (*2* + + +). Now the question presents itself, are all those with the modified carotid (*2*), members of a single stem, and those with the unmodified carotid (2) members of another, similar losses having occurred in both to develop the subjoined series ?

TABLE II.

2 – + +	*2* + + +
2 – – +	*2* – + +
L – + –	*2* – – +
	2 – + –

Or must those types be blended in which the formulæ correspond, irrespective of the carotids ? My placing the carotid index first expresses my belief as to its primary importance ; and this is because the conformation it represents is extremely peculiar and unique among birds, and is therefore less likely to have appeared except as the operation of a specially applied force on a single collection of individuals, the power of transmission being inherited. From this it may be inferred that the ancestral unmodified stem shortly sent off a branch represented by *2* + + +, which persists as such in the *Arinæ*. The main stem and its branch must each have, before long, had a branch of its own, represented by 2 – + + and *2* – + +, which persist as the *Palæornithinæ* and the *Pyrrhurinæ*. From the 2 – + + division sprang the 2 – – + (*Stringopinæ*), and the genus *Cacatua* (L – + –), as did the *2* – – + (*Platycercinæ*) and the *2* – + – (*Chrysotinæ*) from the *2* – + + division. The genus Cacatua is peculiar in having only the left carotid running normally, it must therefore be connected with the normal 2 carotid stem, and many Cacatinnæ, like the Cockateel and the Banksian Cockatoo, are represented by the formula 2 – + +. Some of the true Cockatoos, and some only, have no oil-gland.

My object in giving this somewhat lengthy illustration on the present occasion is to show how much facility a method of formulation affords in the working out of a minor problem of the great doctrine of heredity, such as the classification of the parrots. It makes comparison easy, it facilitates the performance of operations of addition and subtraction, bringing all the stages of the process before the mind's eye without any mental effort. Is it not one to be further developed ?

THE OPTICS OF THE SPECTROSCOPE

NOW that the Spectroscope is becoming an instrument of world-wide use, we think it will be not uninteresting to call attention to some few points that appear to be often overlooked in designing the instrument for various purposes ; and in order to ascertain the best arrangement, we cannot do better than analyse the effects produced in any spectroscope by varying the proportion of its parts. We must, however, premise by saying that the power of an instrument is not altogether dependent on the dispersive power of the prisms, but also on the width of the image of the slit in the eyepiece of the tele-